COMET C/2013 V5 (OUKAIMEDEN): EVIDENCE FOR COMPOSITIONAL HETEROGENEITY AS REVEALED THROUGH INFRARED SPECTROSCOPY.

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Significance of Cometary Compositions: Comets are volatile-rich small bodies lacking gravitational heating and so contain a relatively well preserved compositional record of icy solar system material dating to their formation [1, 2]. Unambiguous diversity in volatile (ice) compositions is well established, even among a limited number of comets. This was first observed through measurements of product species (radicals) at optical wavelengths, in a sample of now over 200 comets [3, 4], and more recently by systematic measurement of 8 – 10 distinct ices contained in their nuclei (these are referred to as “native” ices), through use of IR (and millimeter/sub-millimeter) spectroscopy [5]. When sublimed through solar heating, native ices release parent volatiles (parent molecules) into the coma.

In addition to compositional diversity among comets, a fundamental question is the extent to which individual cometary nuclei may contain material with heterogeneous native ice composition. If seen, this suggests the nucleus as a conglomeration of cometesimals formed in diverse regions of the proto-solar nebula, or at least containing ices exposed to a variety of conditions. This in turn could also imply differential processing of ices prior to their incorporation into the nucleus, for example in the interstellar cloud out of which our solar system formed. Observationally, heterogeneous composition may be revealed over the course of a nucleus rotation, with different active regions contributing to or even dominating the overall gas production as they become exposed to direct sunlight.

Results and Implications: We report pre-perihelion H_2O production rates, and abundance ratios relative to H_2O for eight trace volatiles (CO, CH_4, C_2H_6, H_2CO, CH_3OH, C_2H_2, HCN, and NH_3) in long-period comet C/2013 V5 (Oukaimeden) [6], which passed perihelion on 2014 Sep 28 at heliocentric distance $R_h = 0.625$ AU. Our high-resolution IR (λ between 2.8 and 5.0 µm) observations with Keck 2/NIRSPEC and IRTF/CSHELL revealed (1) most parent volatile abundances were depleted relative to their respective median values among comets, and (2) most significantly, dramatic changes in abundance ratios of CH_3OH and (especially) C_2H_6 on successive dates (Figs. 1 and 2). This heterogenous composition of native ices in Comet Oukaimeden could indicate differing degrees of processing experienced prior to their incorporation into the nucleus.

References: [1] Bockelee-Morvan+ 2004, Comets II, 391; [2] Mumma and Charnley 2011, ARA&A 49:471; [3] A’Hearn+ 1995, Icar 118:223; [4] Schleicher&Bair 2014, Proc ACM, p. 475; [5] Dello Russo+ 2016, Icar 278:301; [6] Guido+ 2013, CBET 3713.

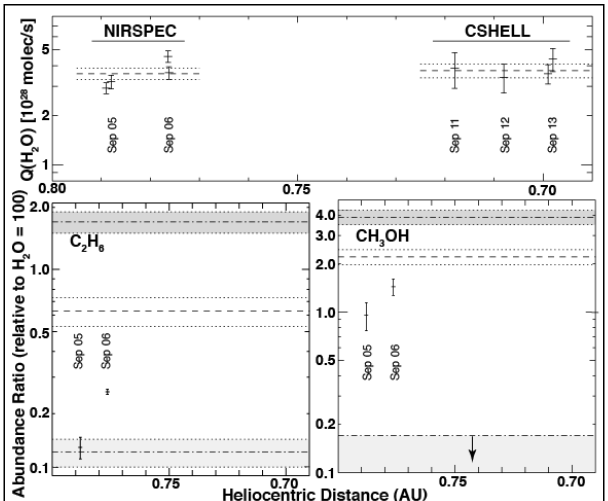

Fig. 1. Upper panel: Water production rates from NIRSPEC (Sep 05/06) and CSHELL (Sep 11-13) observations of C/2013 V5. Lower panels: Abundance ratios (and $\pm1\sigma$ uncertainties) in percent relative to $Q(H_2O)$, showing increases for C_2H_6 and CH_3OH. Dark-shaded regions indicate maximum measured abundances among comets, light-shaded regions indicate minimum measured abundances (the value for CH_3OH is a 3σ upper limit), and unshaded dashed lines are median abundances among comets with dotted lines indicating $\pm1\sigma$ uncertainty values.

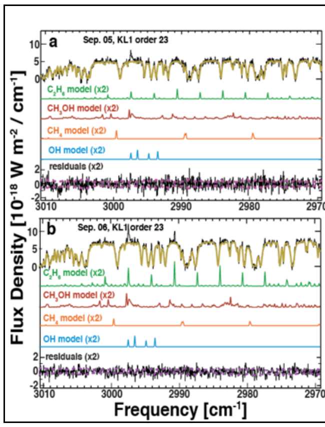

Fig. 2. NIRSPEC spectra of C/2013 V5 on 2014 Sep 05 and 06 ($\lambda/\delta\lambda$ ~24,000), with color-coded, best-fit fluorescence models labeled by molecule. Much stronger C_2H_6 on the latter date is indicative of its large increase (as shown in Fig. 1).